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Hybrid Rocket Propulsion for Sounding Rocket Applications

NASA OSSA

November 12, 1991

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HYBRID ROCKET TECHNOLOGY

- Why Hybrid Rocket Technology ?
- HyFlyer Sounding Rocket

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Camarillo, CA

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Why Hybrid Rocket Technology ?

- **Hybrid Rocket Fundamentals**
- **Hybrid Characteristics**
- **Hybrid Advantages**

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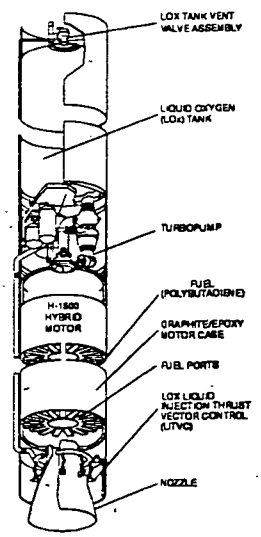
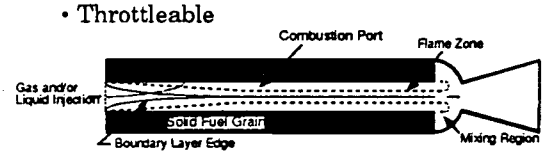
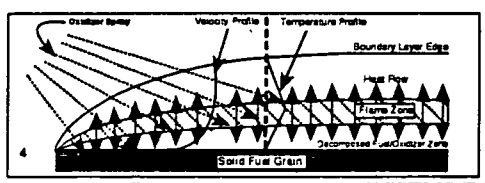
Hybrid Rocket Fundamentals



H-225K Hybrid Motor

- **Solid Hydrocarbon Fuel (e.g., PBD) and Liquid Oxidizer (e.g., LOx)**
- **Combustion Process**
  - Driven by Flow of Oxidizer over Fuel Surface)
- **Fuel/Oxidizer Separation**
  - Safe
  - Throttleable





Hybrid Characteristics

- **Safe - Cannot Explode**
  - No Intimate Mixing of Fuel and Oxidizer
  - Combustion Process is Diffusion Limited
- **Throttleable**
  - Thrust Proportional to Oxidizer Flowrate
- **Scaleable**
  - Thrust Scales with Internal Surface Area and Oxidizer Mass Flux
- **Environmentally Clean**
  - Fuel Selection and High Flame Temperature Result in Clean Exhaust Products

Hybrid Advantages

- **High Performance**
- **Low Cost Due to Fundamental Safety**
- **Low Cost Due to the Nature of Hybrids**
- **Low Risk**
- **Flexible**

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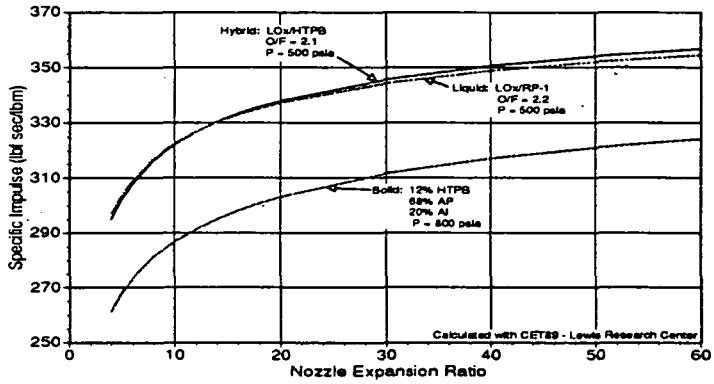
Hybrid Advantages *American Rocket Company*

High Performance

- I_{SP} is Equivalent to LOx/Hydrocarbon Engines (e.g. Saturn V F-1 1st Stage Engine)--10-15% Higher than Solid Motors
- Throttleability Increases Payload to Orbit

IDEAL VACUUM SPECIFIC IMPULSE FOR A HYBRID, SOLID, and LIQUID ROCKET MOTOR



Hybrid Advantages *American Rocket Company*

Low Cost Due to Fundamental Safety

- Safe Technology Reduces Costs in All Phases of Development, Production and Operations
- No Remote/Automated Production Facilities Required
- Anomalous Events Do NOT Destroy Test Facilities or Launch Pads
- No Restrictions on Personnel Activity In Any Phase of Development, Production or Operations
- No Special Handling or Transportation Requirements
- Lower Insurance Costs in All Phases

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Hybrid Advantages — *American Rocket Company*

Low Cost Due to the Nature of Hybrids

- **Low Production Costs**
  - Reduced Complexity
  - Few Critial Tolerances
  - Short Production Cycle (weeks)
  - Low Production Facilities Costs

} *Standard Light Industrial Facilities Are Adequate*

- **Low Materials Costs**
  - No Strategic Materials
  - Multiple Commercial Sources
  - Many Material Options
- **Low Operations Cost**
  - Reduced Manpower Requirements
  - Reduced Inspection Requirements

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Hybrid Advantages — *American Rocket Company*

Low Risk

- **Non-Explosive Therefore No Catastrophic Detonations**
- **Command Shutdown In the Event of Problems Affords Safe Abort**
- **Safe Engine Idle Allows Engine Verification Prior to Full Thrust**
- **Insensitive to Environmental Conditions**
- **Robust Combustion Cycle**
  - Resistant to Manufacturing Defects
  - Self-Damping
- **Safety = Less Complexity = High Reliability**
- **No Uninsurable Liability**
- **No Hazardous Materials and Clean Exhaust = No Environmental Risk**

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Flexible

- **Rapid Response to Customer Requirements**
  - Simple Designs Allows Product Customization
  - Short Development Cycle (Months)
- **Facilitization**
  - Commercial Production Facilities and Short Lead Time Parts Permits Buildup of Production Capability to Match Demand
- **Surge Capability**
  - No Specialized Manufacturing Equipment
  - No Long Lead Time Items
  - No Strategic Materials

Why Haven't Hybrids Been Used Before ?

- **Initial Difficulty in Maintaining Stable Hybrid Combustion**
- **Early Focus on "Performance At Any Cost"**
  - Designs Optimized for Maximum I_{sp}
  - Military ICBM Requirements Drove All Initial Designs
- **Initial Emphasis on Solids Based on System Readiness**
  - ICBM Requirement
- **Liquids Developed Intensively For Apollo Program**
- **Larger Database on Solids and Liquids Made Hybrids Higher Risk Option for Later Programs**
- **Large Investment in Facilities to Produce and Test Solids and Liquids Supported Predisposition to Those Technologies**

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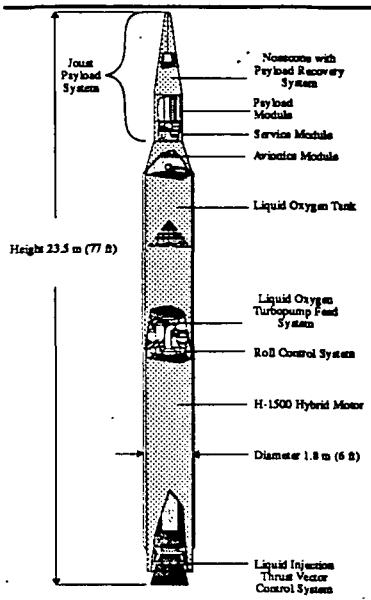
The HyFlyer Suborbital Vehicle



- Provides 11 Minutes of Microgravity Time for a Joust-class Payload
- Based on AMROC H-1500 Liquid Oxygen/Polybutadiene Hybrid Rocket Motor
- In Development to Validate H-1500 Motor for Use in Aquila Orbital Vehicle

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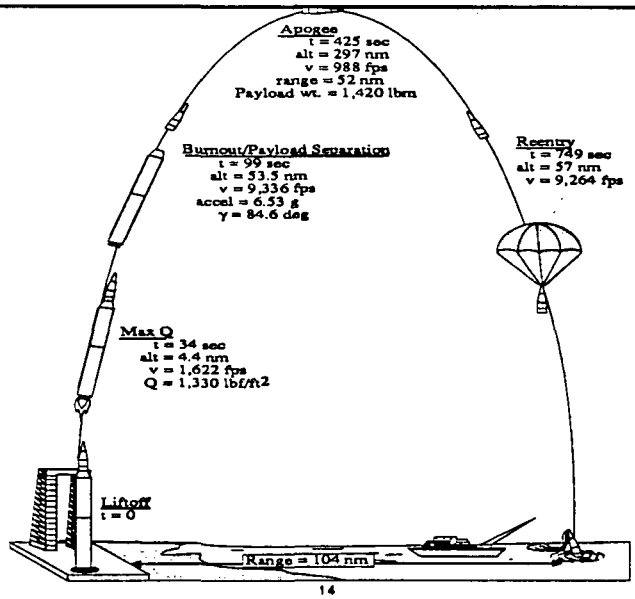
HyFlyer Mission Profile



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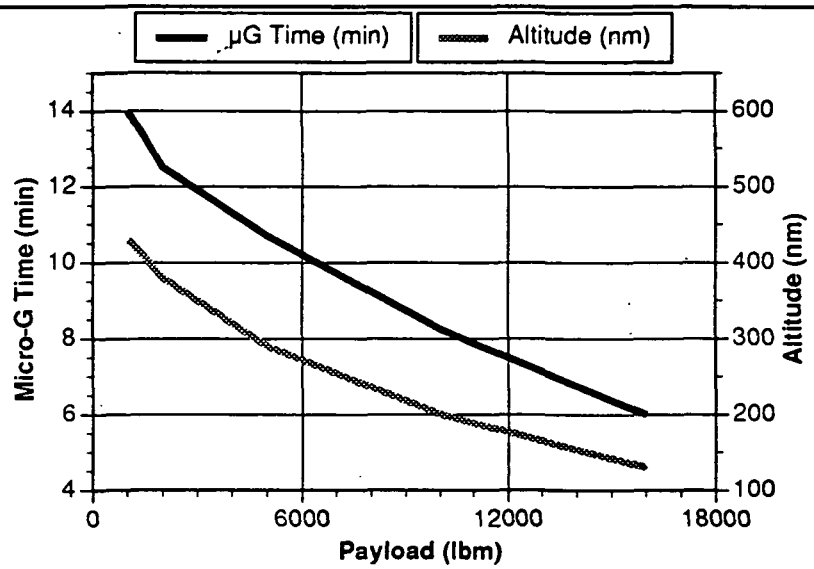
HyFlyer Performance



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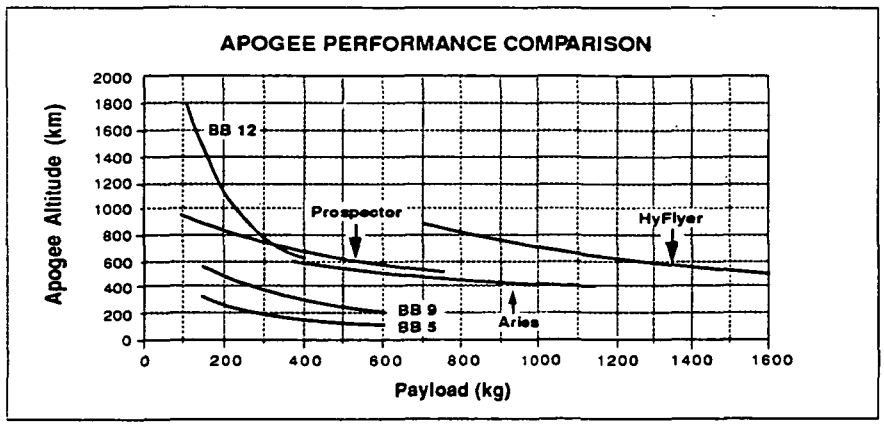
HyFlyer Comparitive Performance



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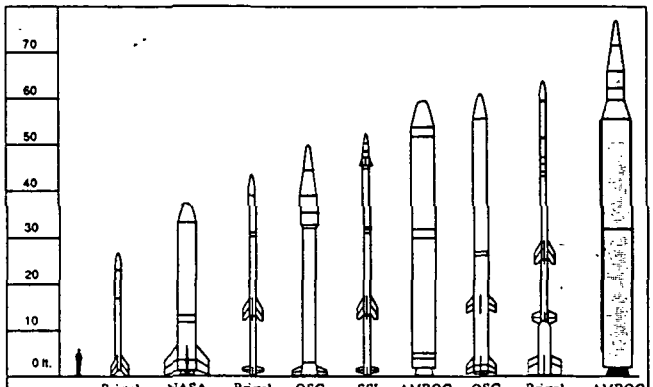
Sounding Rocket Fleet



	Bristol Black Brant VB	NASA Aries	Bristol Black Brant IX	OSC Prospector	SSI Starfire	AMROC SET-1	OSC Starbird	Bristol Black Brant XII	AMROC HyFlyer
Payload Capability (Kg.)	150 - 600	350 - 1150	150 - 600	100 - 500	150 - 600	---	200 - 2,400	100 - 400	750 - 7,270
Microgravity Time (min.)	3 - 7	8 - 11	6 - 11	12-15	6 - 11	---	6 - 24	12 - 24	6 - 14

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HyFlyer Summary

- **AMROC's HyFlyer is the Mac Truck of Sounding Rockets**
  - Unique Heavy Lift Capability - 8 Tons!
- **72" Diameter Booster - Large Payload Volume Available**
- **Developed to Validate Hybrid Propulsion For AMROC's Orbital Vehicle - Aquila**
- **Available Late 1993**
- **Estimated Launch Cost ≈ $3.5M**